

Solute Transport (Ch. 6)

1. The need for specialized membrane transport systems.
2. Passive vs. Active Transport
3. Membrane Transport Mechanisms

Why the need for specialized transport systems?

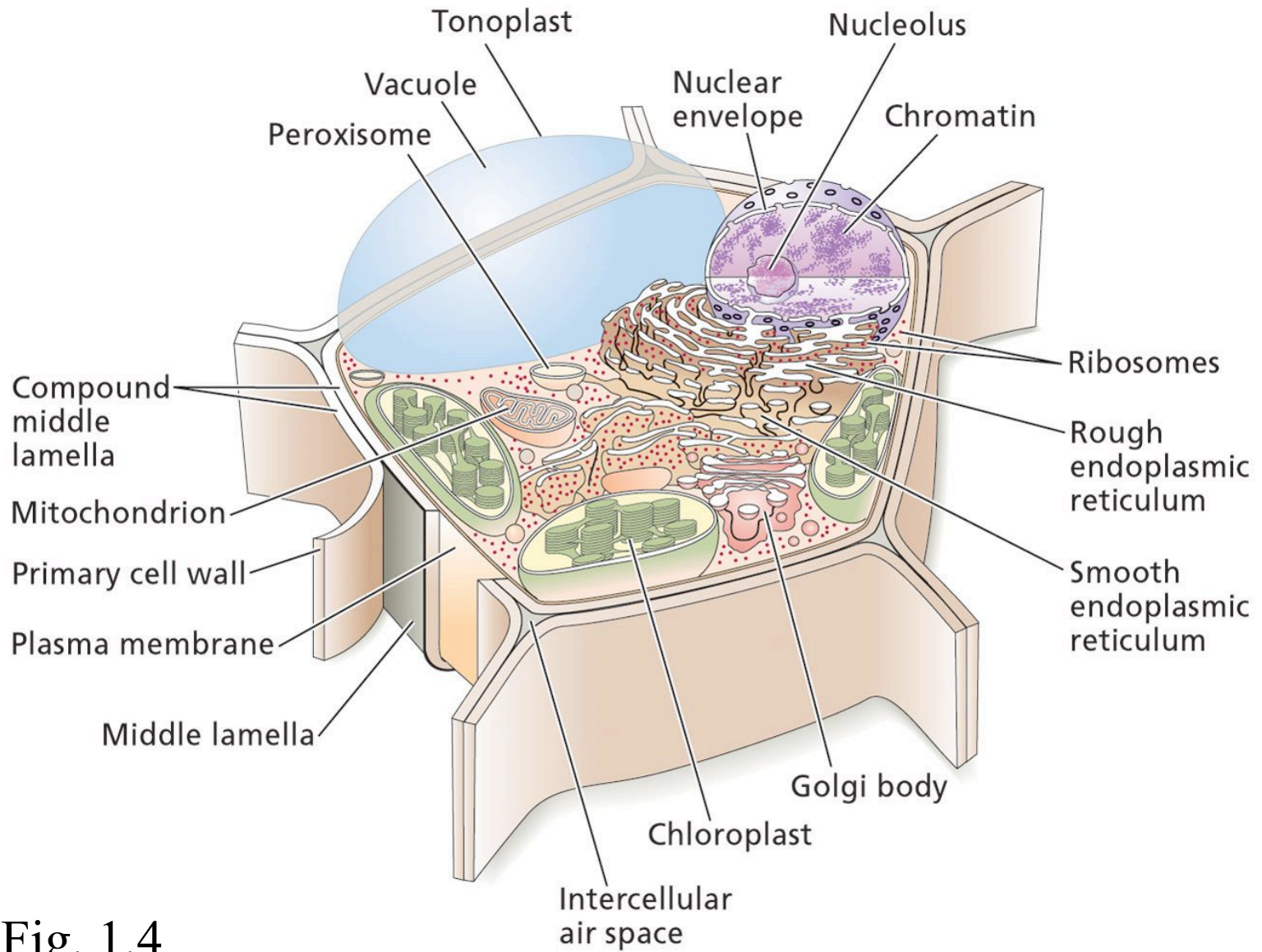


Fig. 1.4

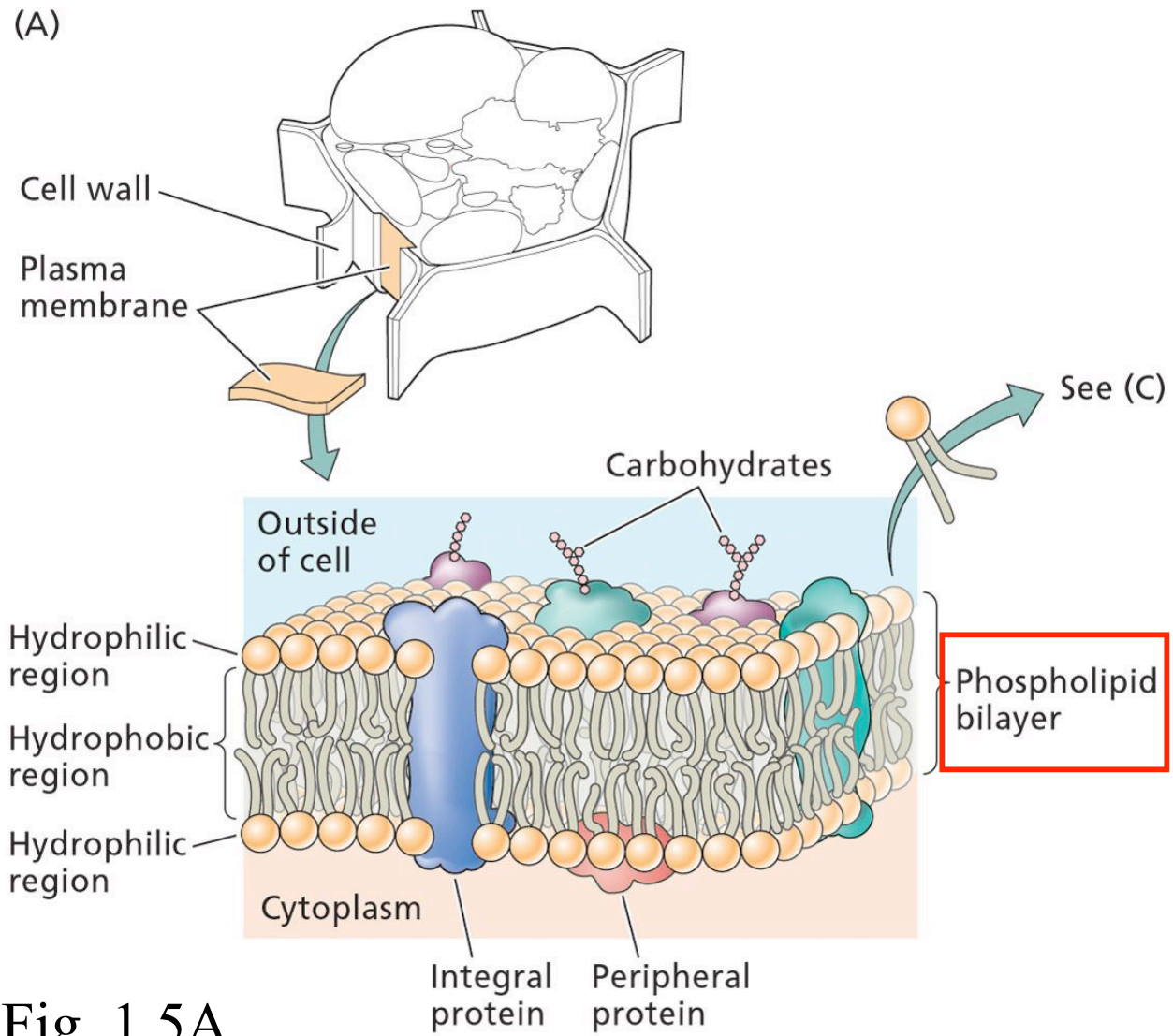


Fig. 1.5A

That the permeability of biological membranes differs from that of a simple phospholipid bilayer indicates that transporters are involved.

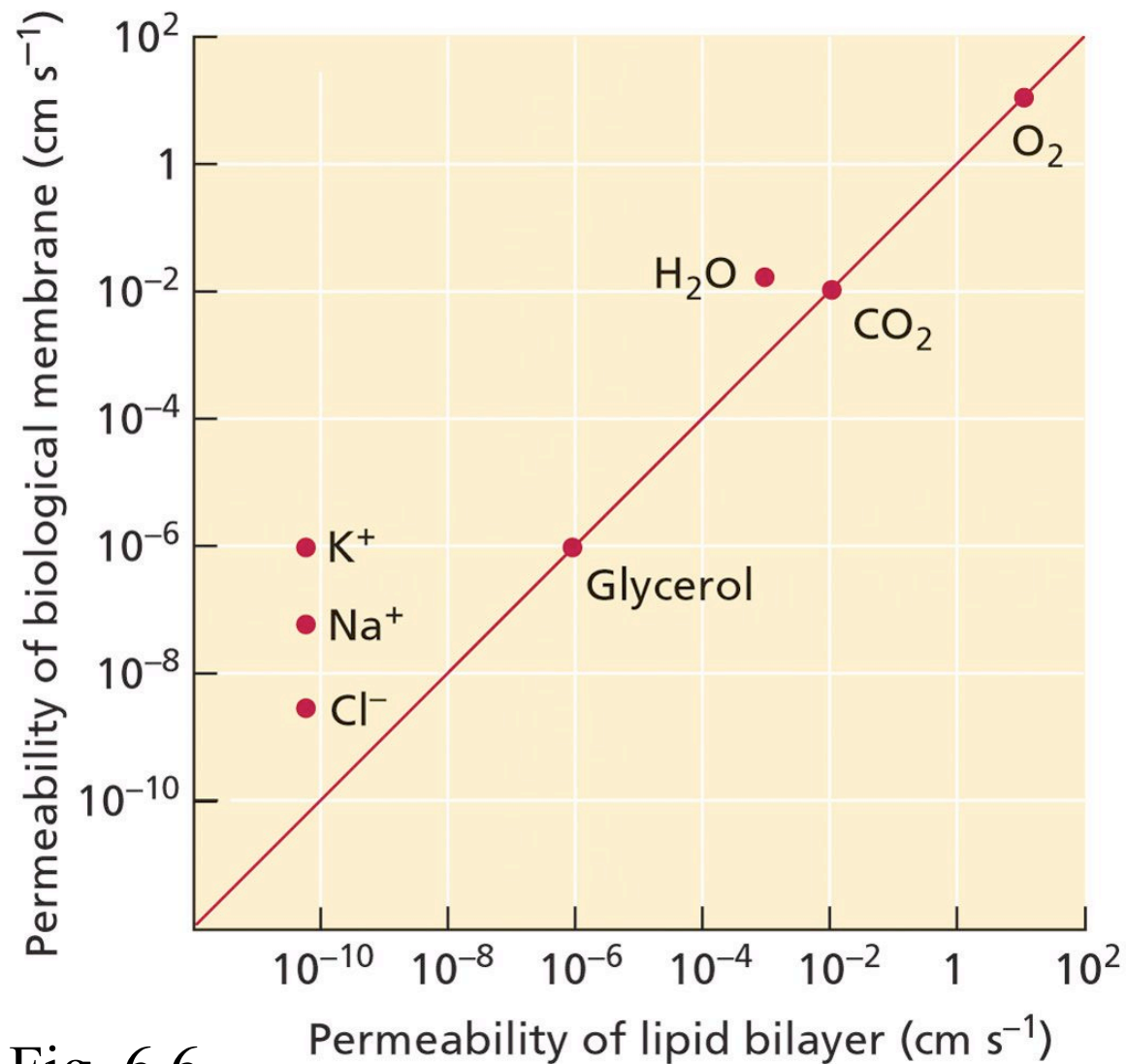


Fig. 6.6

Passive vs. Active Transport

Passive transport requires no energy input, $\Delta G < 0$

Active transport requires energy, $\Delta G > 0$

Whether active or passive transport is required is determined by the chemical potential of a solute on either side of a membrane.

We can use the ΔG concept to understand the chemical potential.

Chemical potential difference

1. Concentration component

$$2.3 RT \log (C_j^i / C_j^o)$$

What is the concentration influence on where the solute will tend to move spontaneously?

2. Electrical component

$$z_j F E$$

What is the electrical influence on where the solute will tend to move spontaneously?

Movement along electrical and concentration gradients
(from Lecture 3)

$$\Delta G = zF \Delta E_m + 2.3 RT \log(C_2/C_1)$$

At equilibrium ($\Delta G = 0$) can rearrange this as:

$$\Delta E_m = -2.3(RT/zF) \log(C_2/C_1)$$

Nernst potential

- The difference in electrical potential (voltage) between two compartments at equilibrium with respect to a given solute.
- The membrane electrical potential at which the concentration and electrical influences on a solute's movement are exactly balanced, so there is no net movement.

The Nernst
Equation

$$\Delta E_j = \frac{2.3RT}{z_j F} (\log C_j^o / C_j^i)$$

Note that outside conc. is in numerator, inside is in denominator. Not C_{to}/C_{from} as we used before in ΔG eqn.

ΔE_j is the membrane potential (inside relative to outside), and is negative for the plant plasmamembrane.

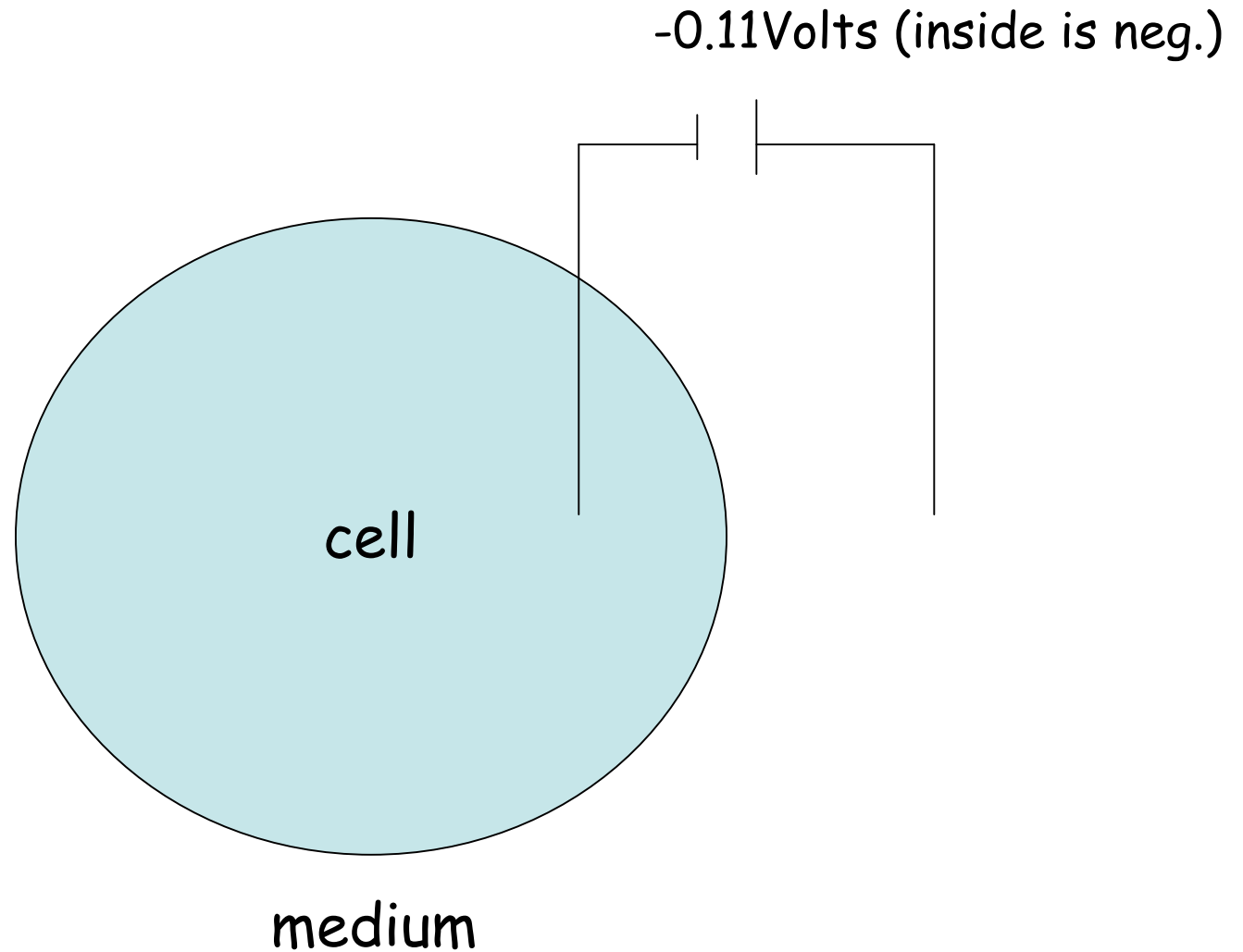
See that for an anion (z negative), Nernst predicts $C_j^o / C_j^i > 1$ and for a cation (z positive), Nernst predicts $C_j^o / C_j^i < 1$

How can we use the Nernst Equation to understand the difference between passive and active transport?

Compare the concentration gradient predicted by the Nernst Equation to that actually observed.

If they differ, then active transport must be involved.

What concentration gradient of an anion or cation would be maintained by the membrane potential without an input of energy?



Examples of predicted and observed concentration differences between outside and inside of pea root cells.

TABLE 6.1

Comparison of observed and predicted ion concentrations in pea root tissue

Ion	C_j^o Concentration in external medium (mmol L ⁻¹)	C_j^i Internal concentration (mmol L ⁻¹)	
		Predicted	Observed
K ⁺	1	74	75
Na ⁺	1	74	8
Mg ²⁺	0.25	1340	3
Ca ²⁺	1	5360	2
NO ₃ ⁻	2	0.0272	28
Cl ⁻	1	0.0136	7
H ₂ PO ₄ ⁻	1	0.0136	21
SO ₄ ²⁻	0.25	0.00005	19

Source: Data from Higinbotham et al. 1967.

Note: The membrane potential was measured as -110 mV.

Predict higher internal than external for cations because the membrane potential attracts cations.

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Source: Data from Higinbotham et al. 1967.

Note: The membrane potential was measured as -110 mV.

Predict lower internal than external for anions because the membrane potential repels anions.

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Note: The membrane potential was measured as -110 mV.

Observed internal matches predicted internal:
conclude no energy required to maintain this condition.

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Source: Data from Higinbotham et al. 1967.

Note: The membrane potential was measured as -110 mV.

Observed very different than predicted:
conclude energy (active transport) is required
to maintain this condition.

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Source: Data from Higinbotham et al. 1967.

Note: The membrane potential was measured as -110 mV.

Active transport is moving cations out of cell and anions into cell.

TABLE 6.1

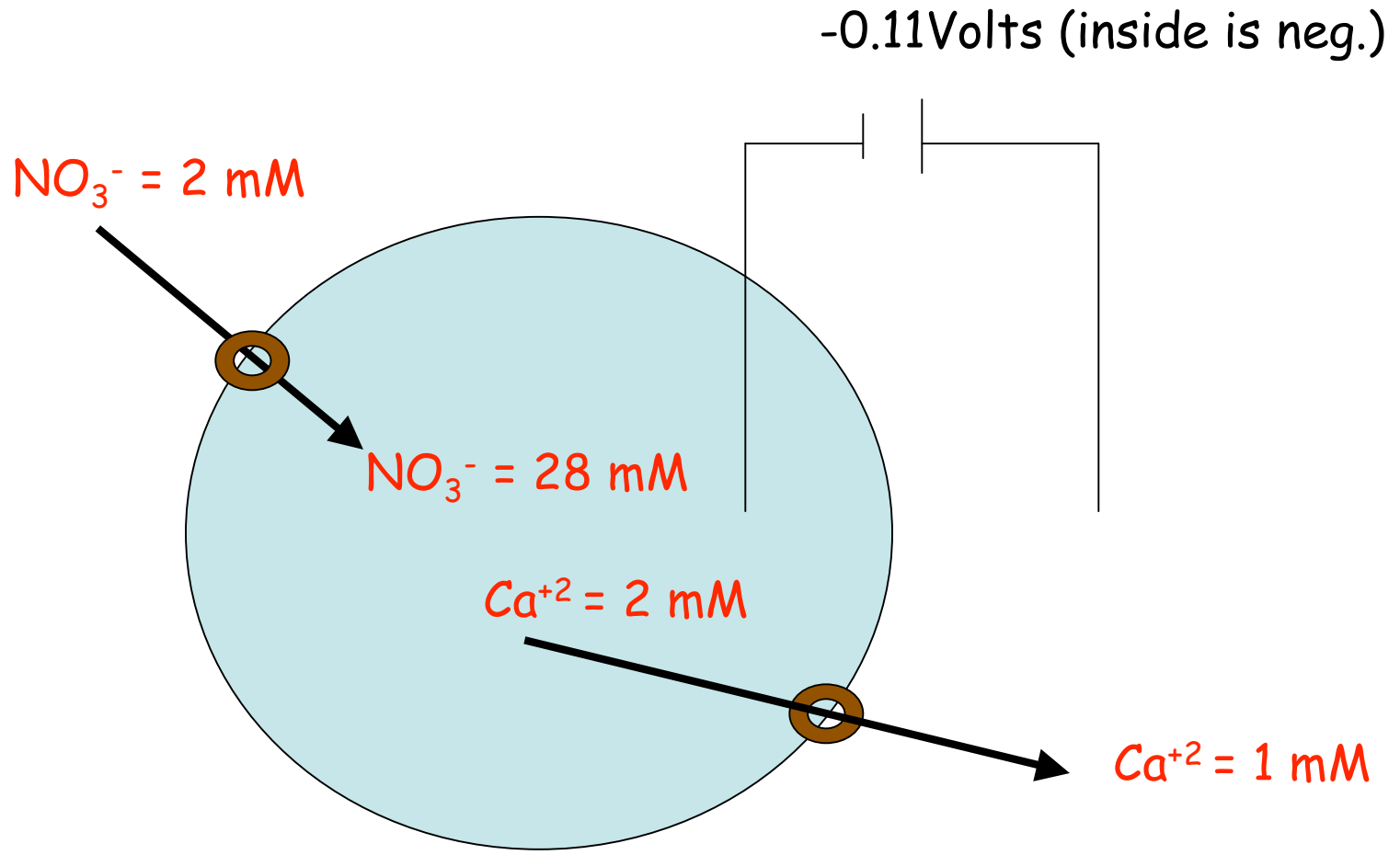
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Source: Data from Higinbotham et al. 1967.

Note: The membrane potential was measured as -110 mV.

Active transport is maintaining $[\text{NO}_3^-]$ internal at higher than expected and $[\text{Ca}^{+2}]$ internal at lower than expected.



Plasmamembrane and the tonoplast are sites of much ion transport.

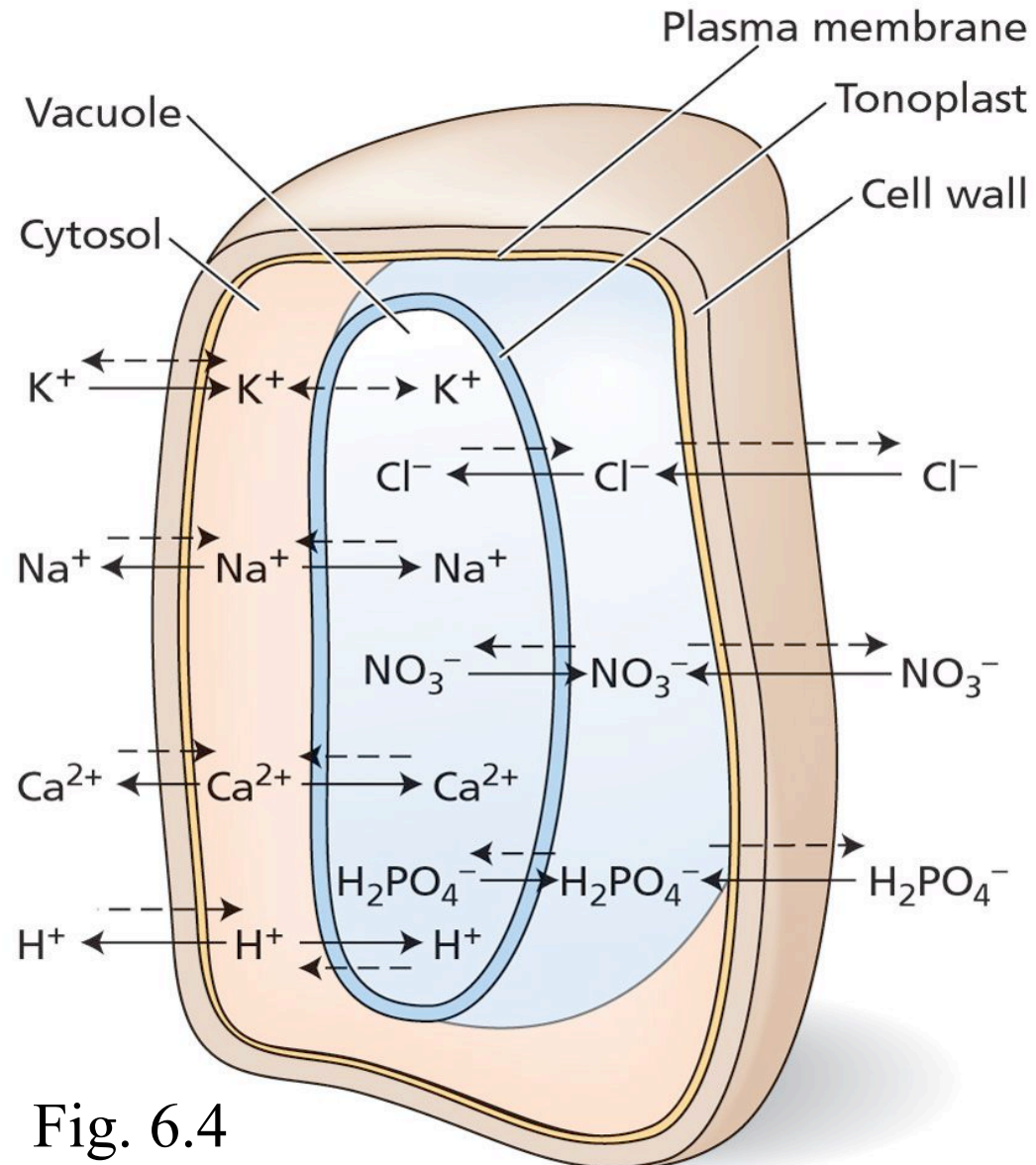
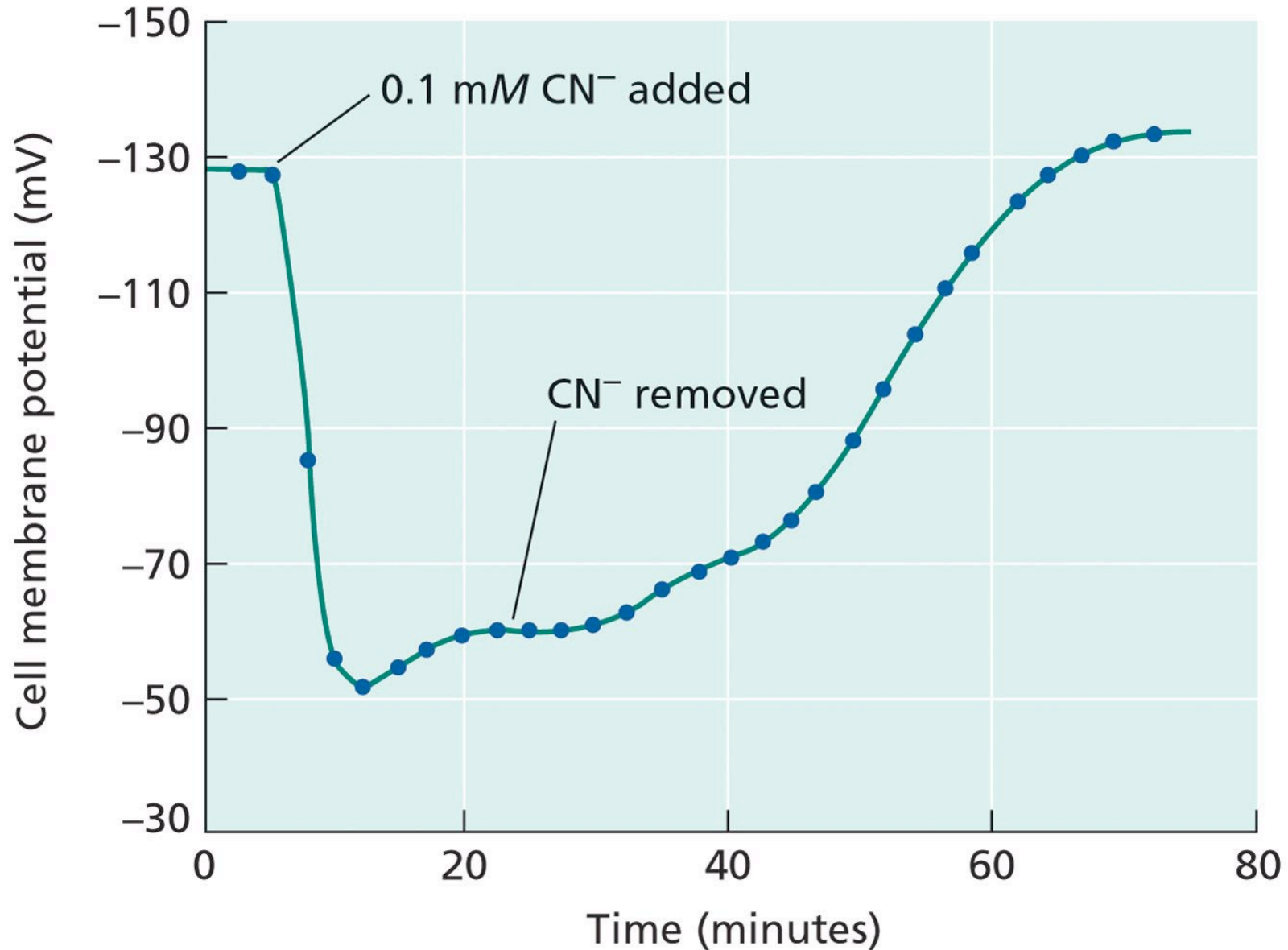
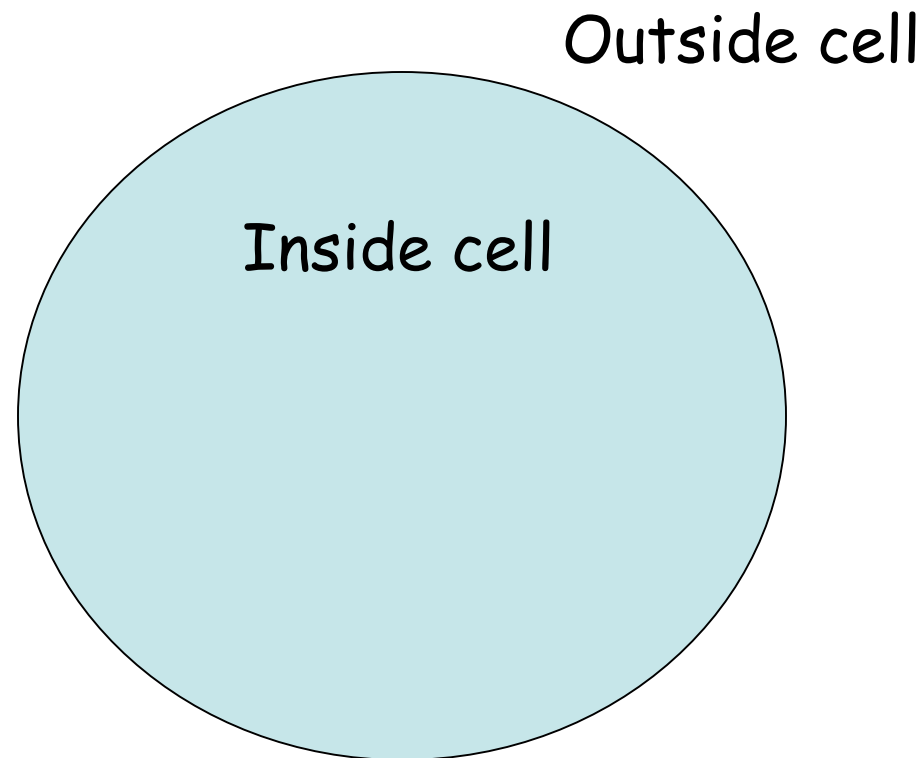


Fig. 6.4

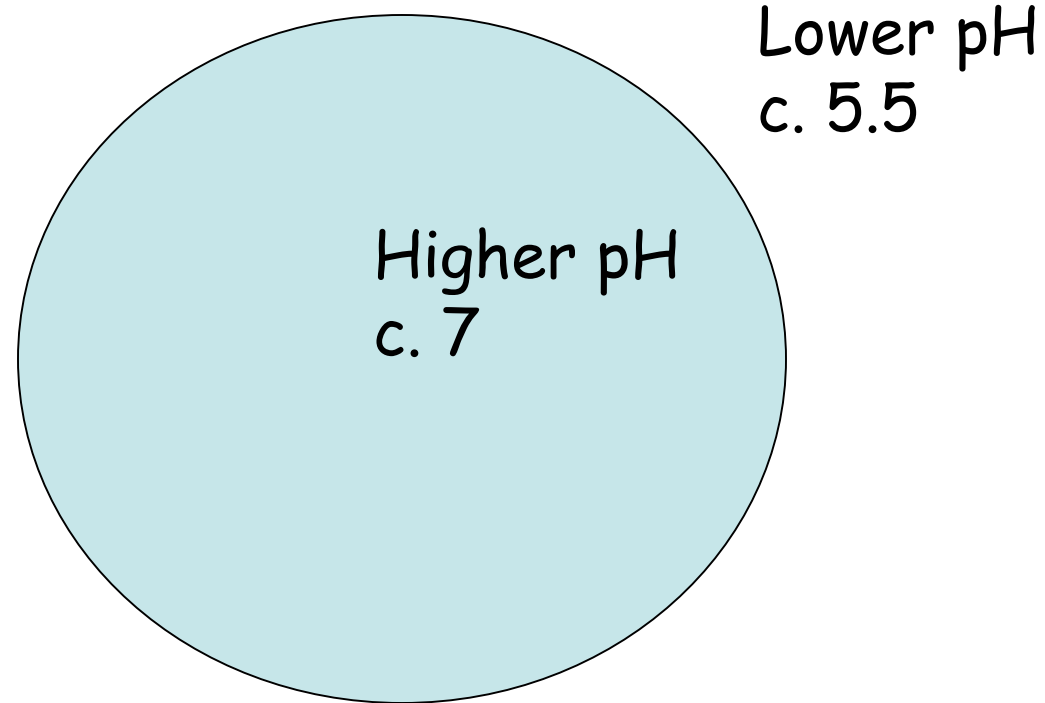
Maintenance of cell membrane potential requires energy produced by respiratory metabolism



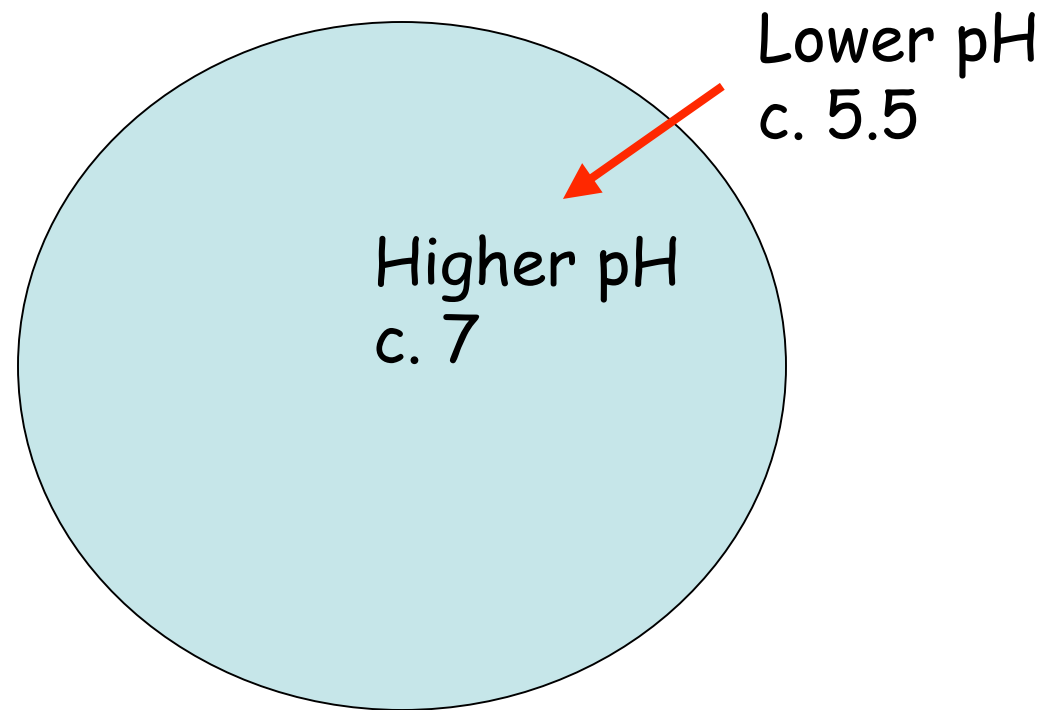
- 1. What is the pH gradient across plasmamembrane?*
- 2. How is the pH gradient maintained?*
- 3. How is pH gradient related to electrical potential?*



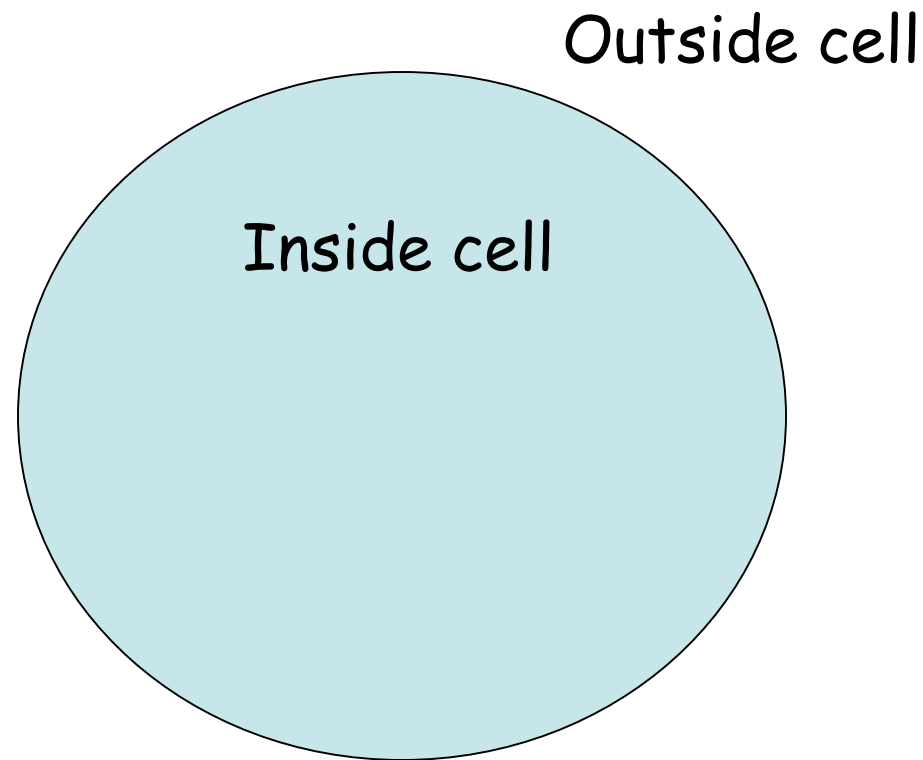
*What is the pH gradient across plasmamembrane?
Which way will H^+ move spontaneously?*

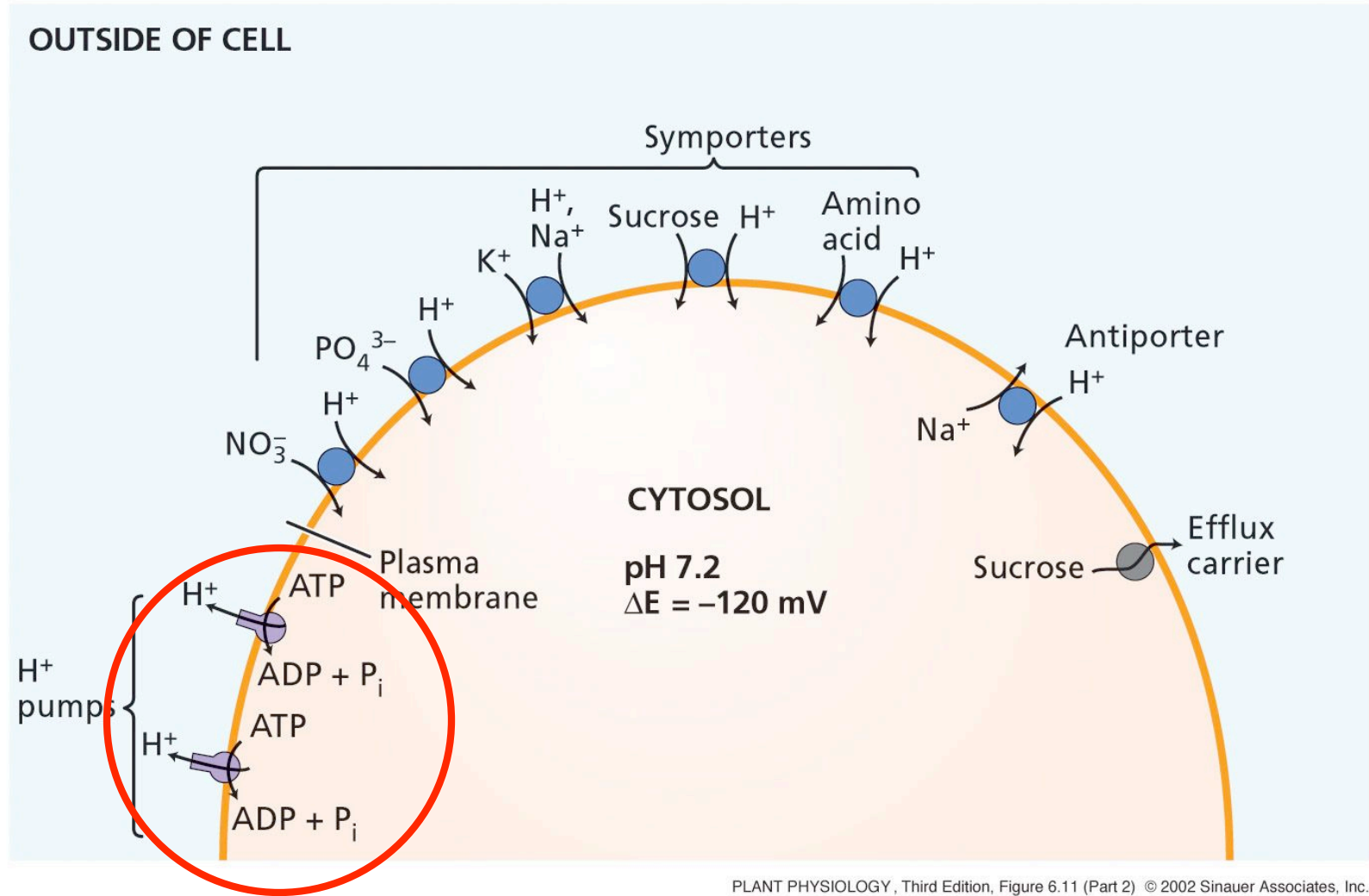


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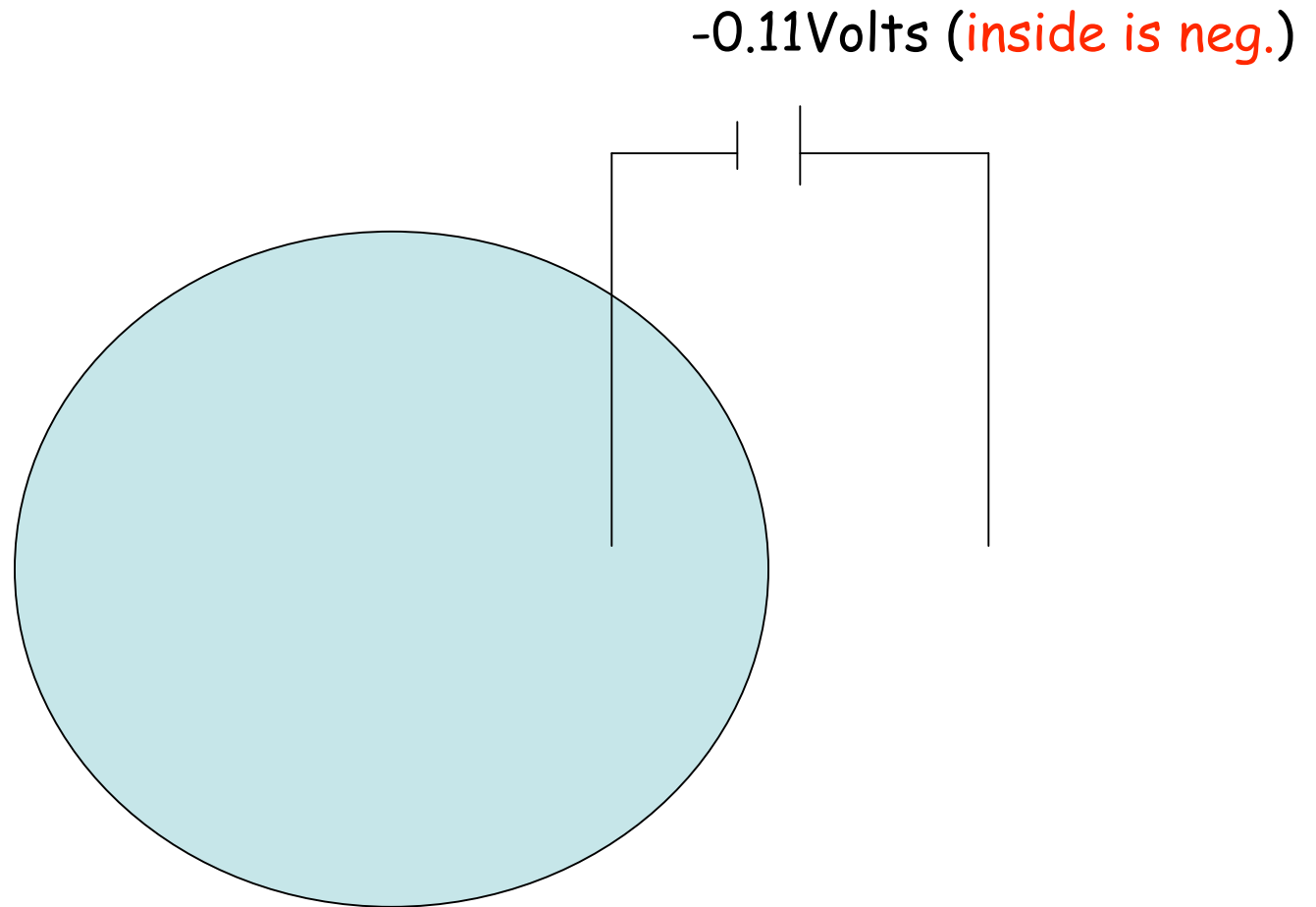
1. *What is pH gradient across plasmamembrane?*
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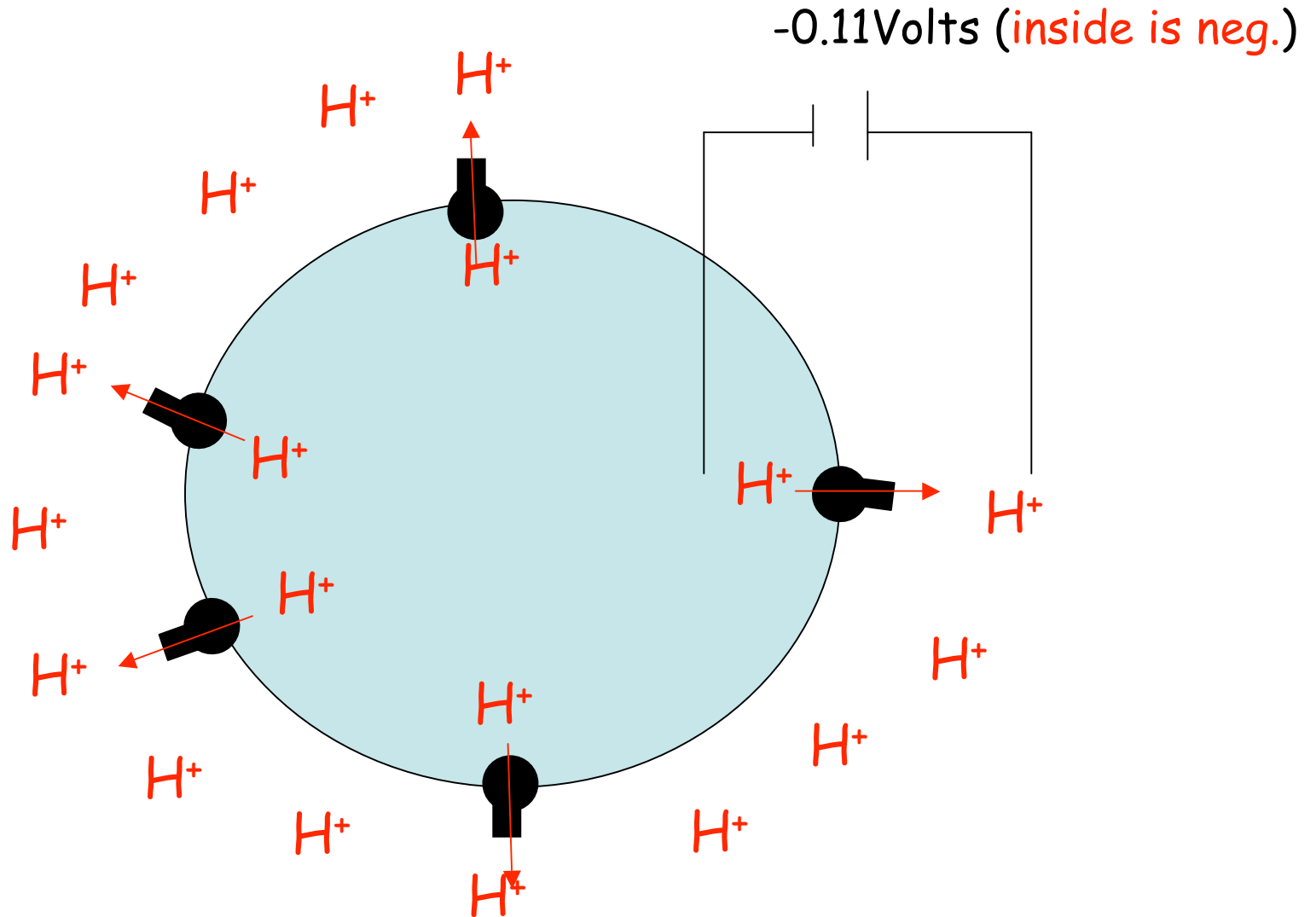
Proton pumping ATPases maintain pH gradients.
 This is a major use of ATP in all living cells!

1. *What is pH gradient across plasmamembrane?*
2. *How is the pH gradient maintained?*
3. *How is pH gradient related to electrical potential?*



How is pH gradient related to electrical potential?

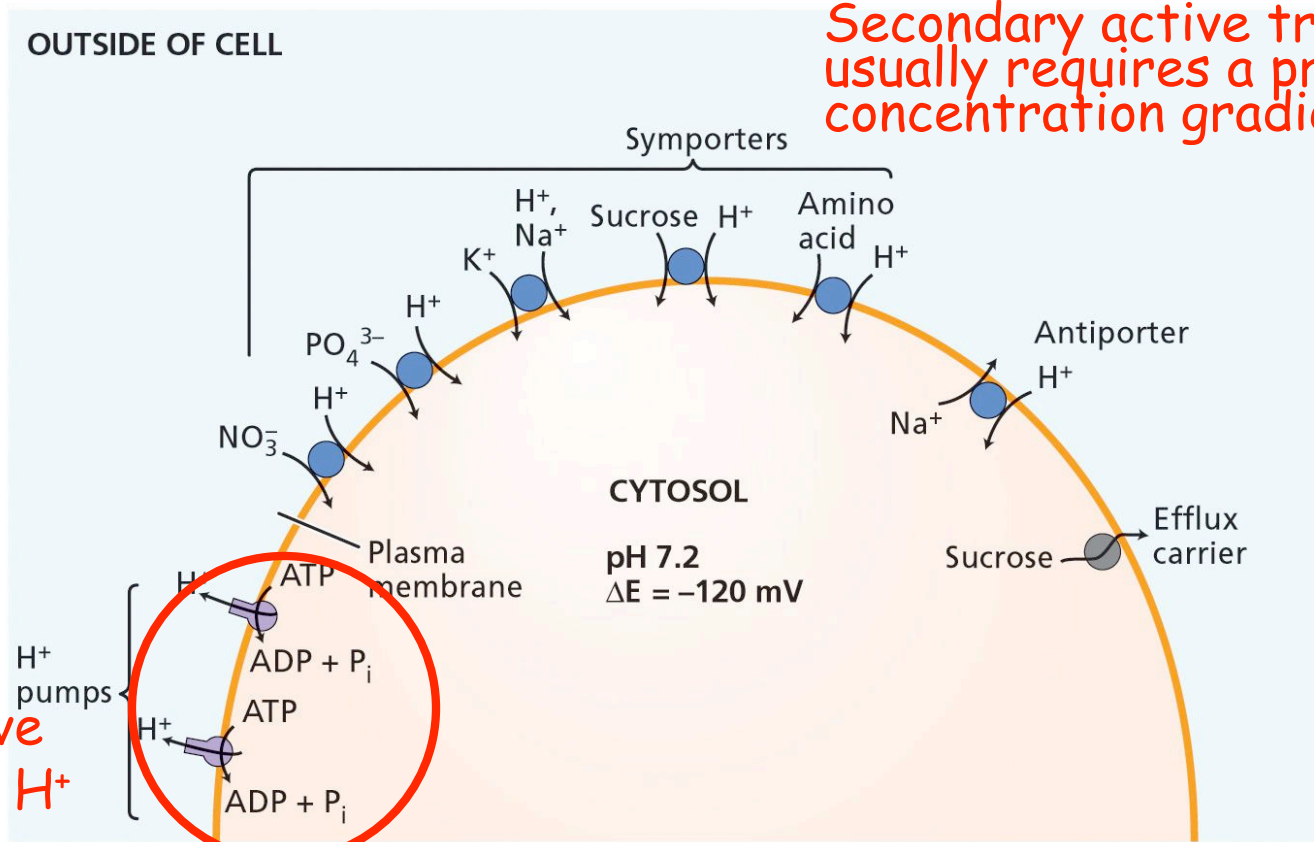
Pumping of charged molecules (protons) generates the membrane potential.



So, the proton pumping ATPases create both the proton concentration gradient (pH gradient) and the membrane electrical potential.

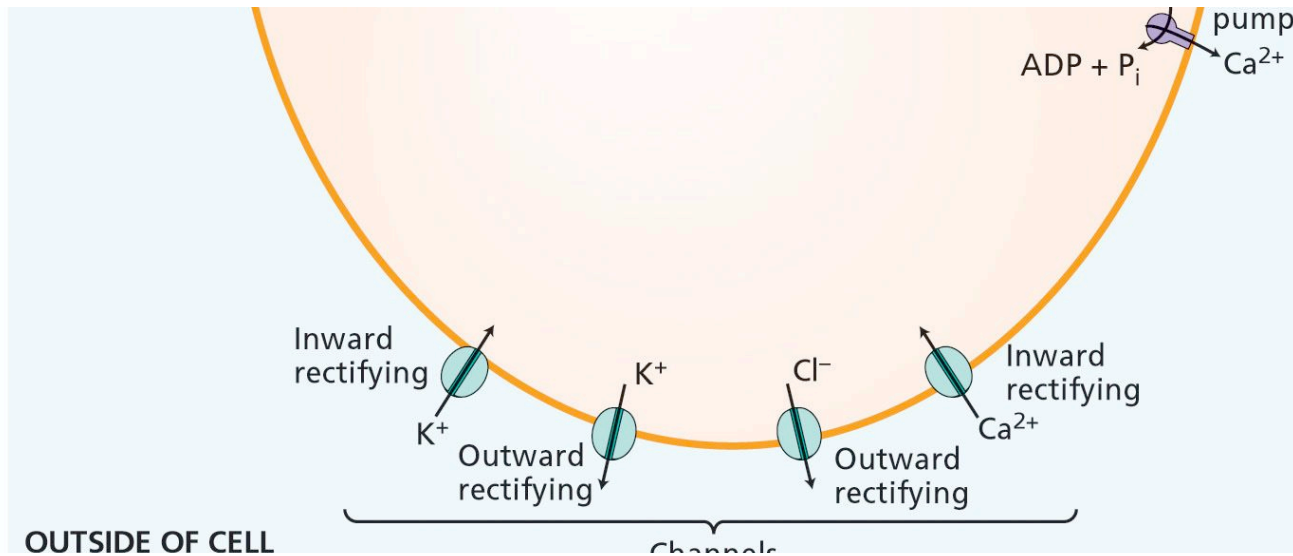
- The electrical gradient explains why some ions are distributed unequally across the membrane, even without the direct input of energy.
- The proton concentration gradient provides the free energy for many kinds of secondary active transport.

Secondary active transport usually requires a proton concentration gradient (p.m.f.).



Primary active transport of H^+

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Primary active transport: Energy use is directly linked to transport,
e.g. ATP is hydrolyzed as transporter moves a solute across
membrane

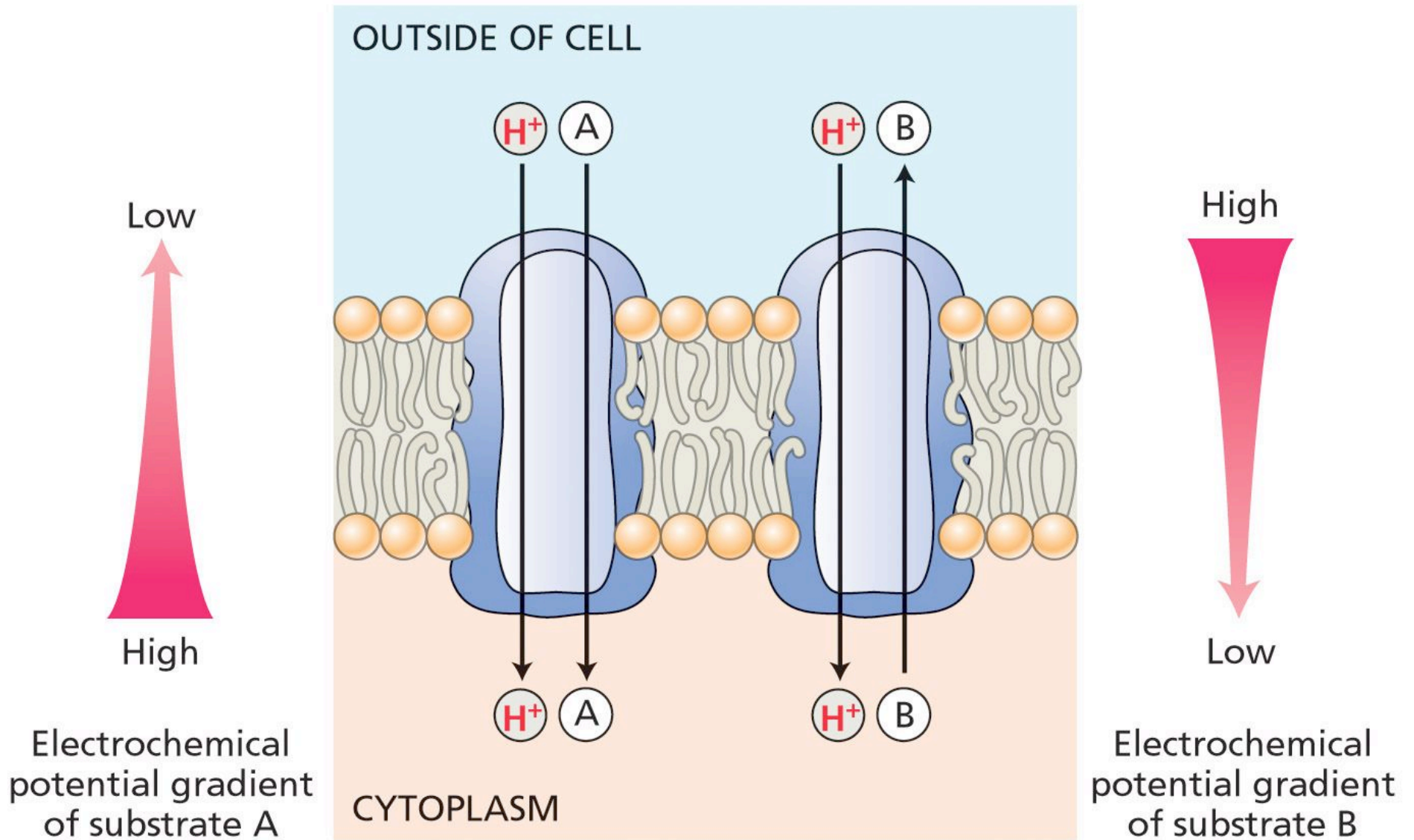
Secondary active transport: Energy use establishes conditions for
transport, which itself does not directly require energy.
e.g. establishment of a proton motive force by a proton pumping
ATPase (primary active transport) then allows H⁺/sucrose co-
transport (secondary active transport).

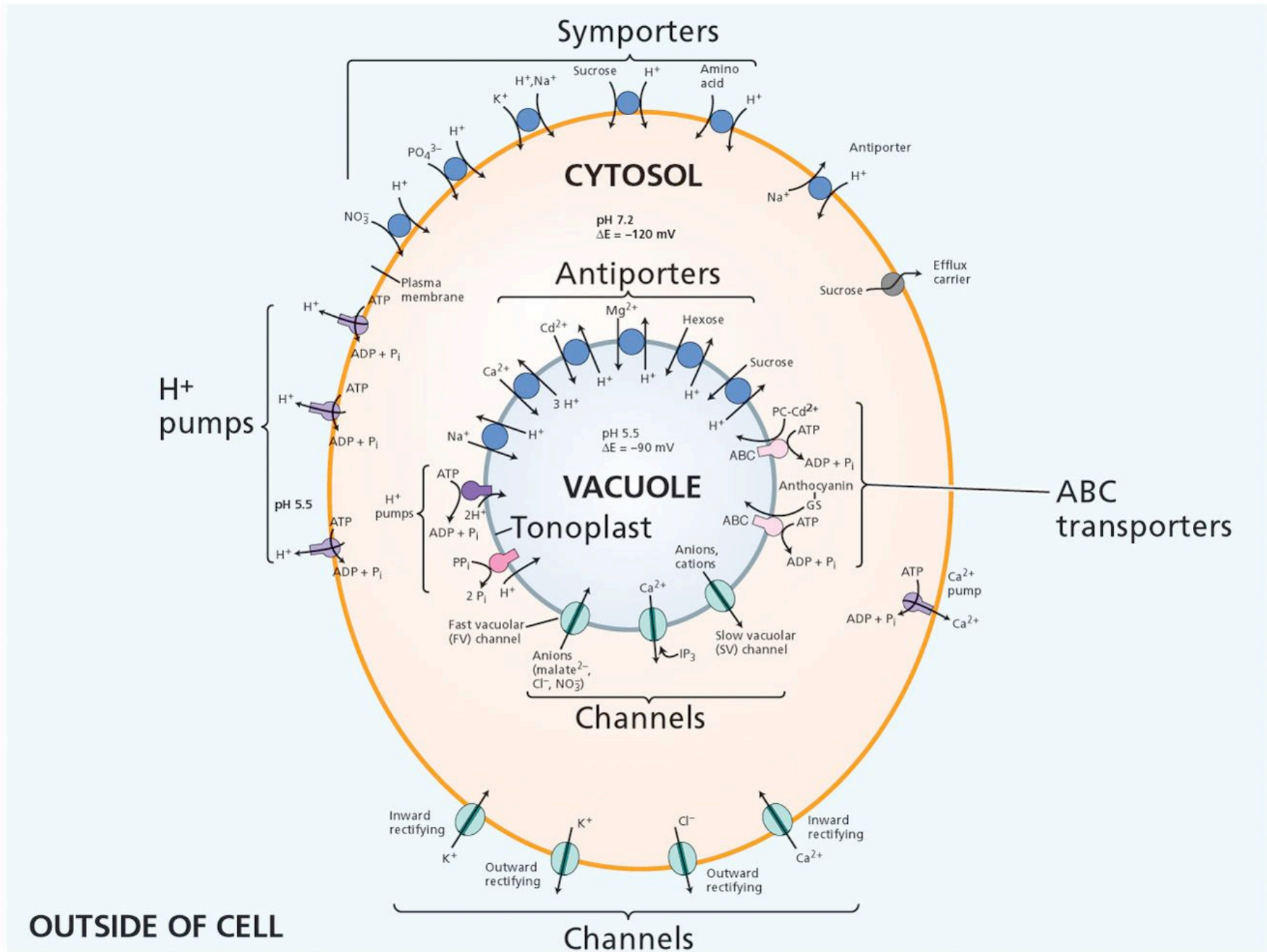
Secondary active transporters

Symports and Antiports

(A) Symport

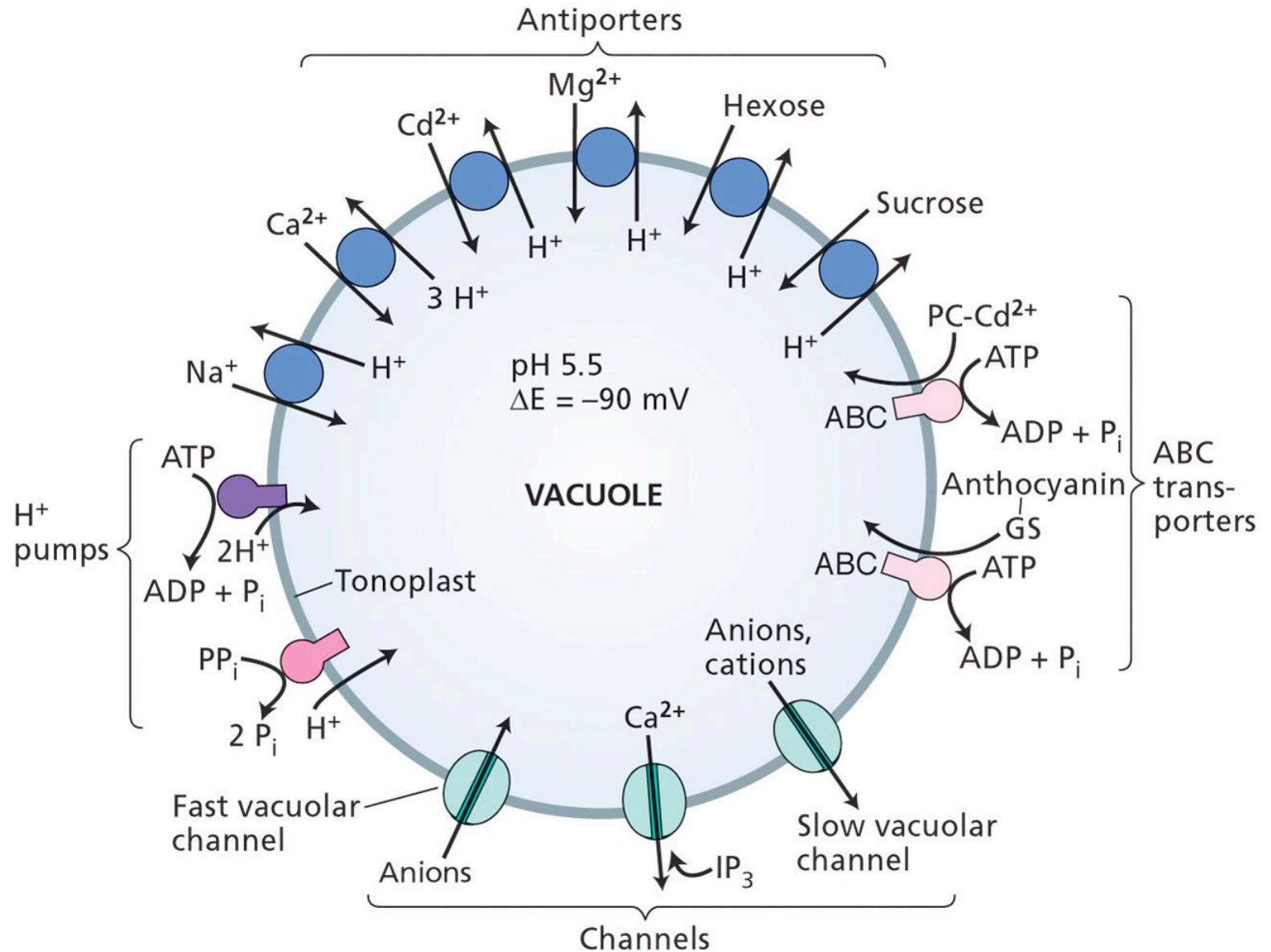
(B) Antiport

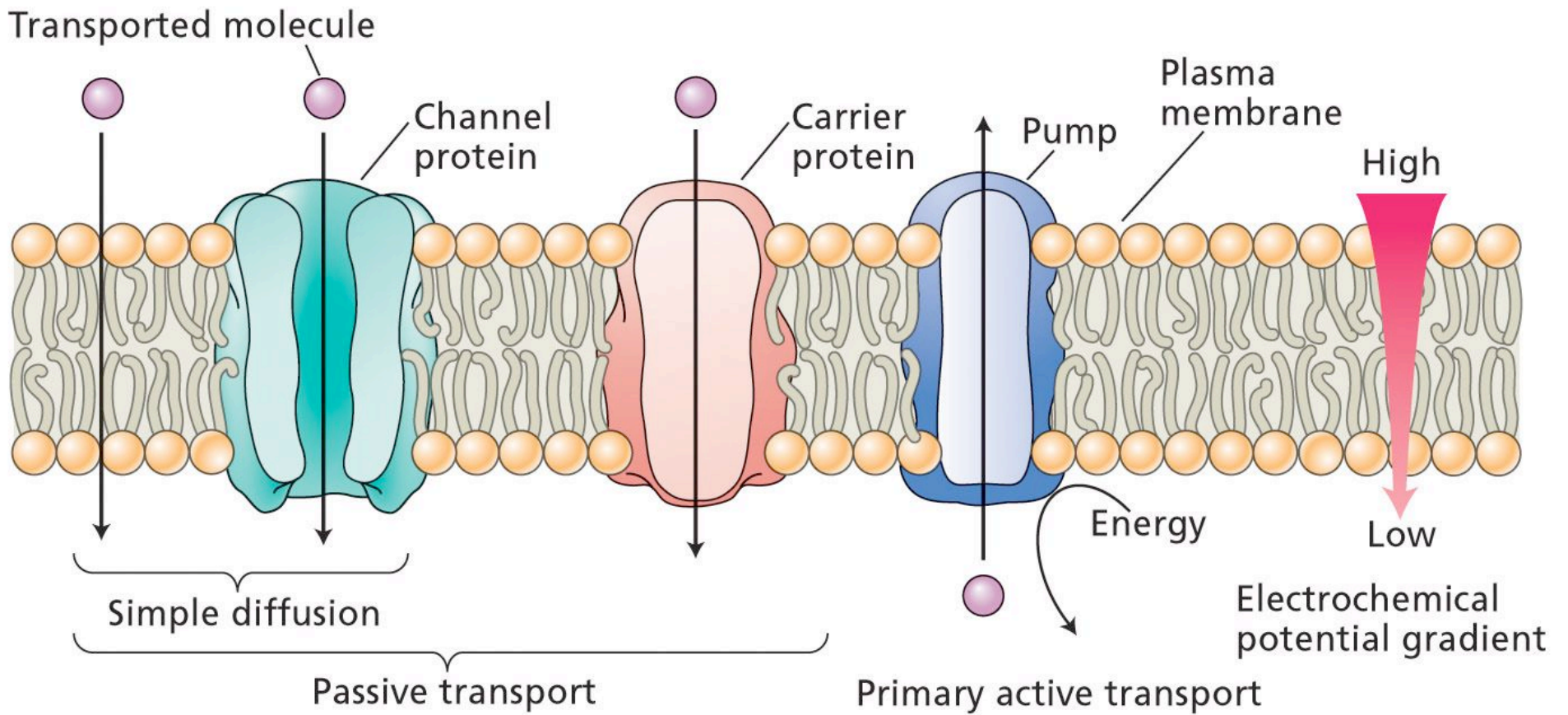




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Proton pumping ATPases are inverted on vacuole membrane.





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(A)

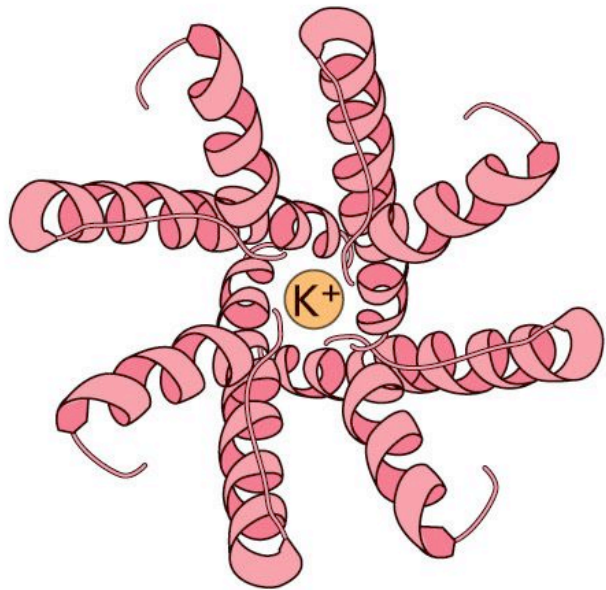
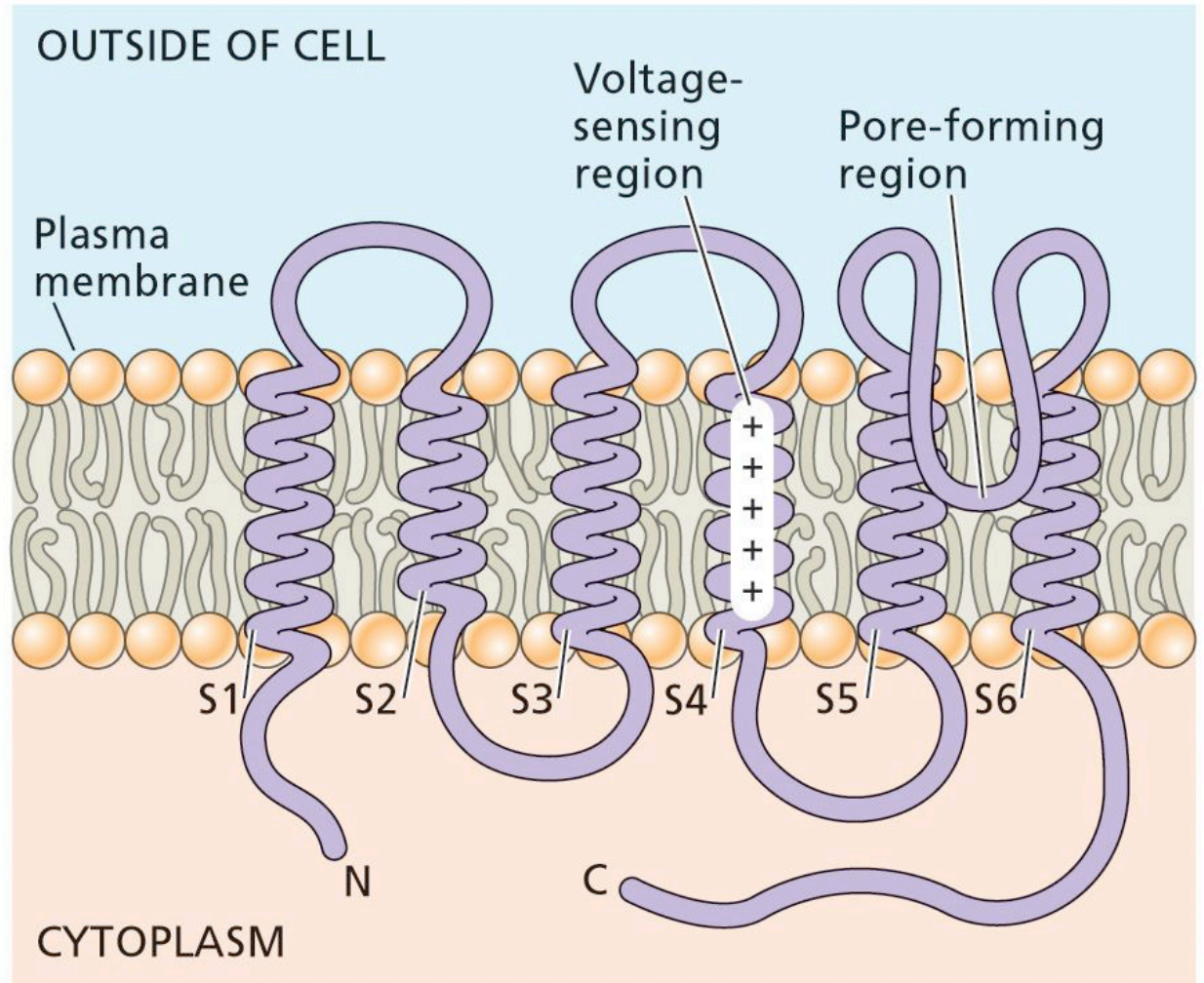


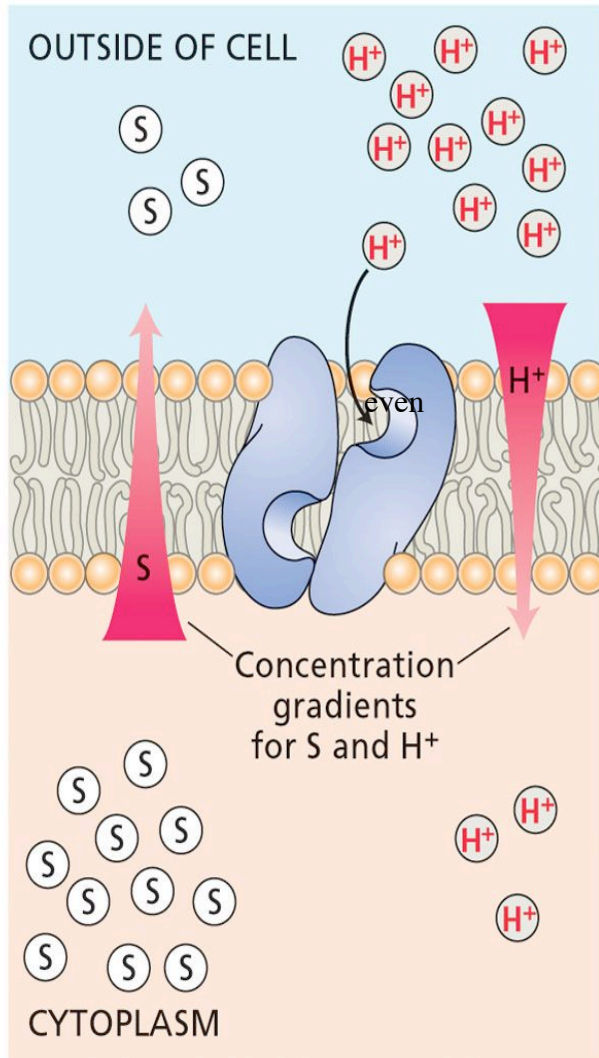
Fig. 6.8

(B)

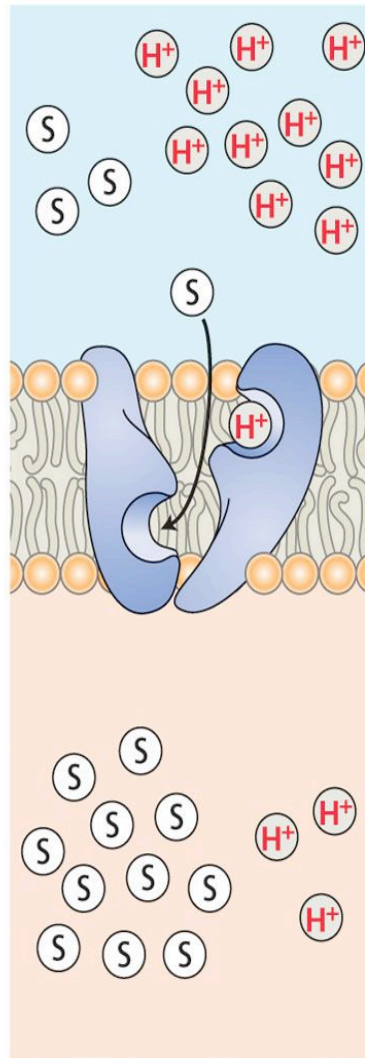


Transport of a solute against its concentration gradient can occur by coupling it to proton transport with its concentration gradient.

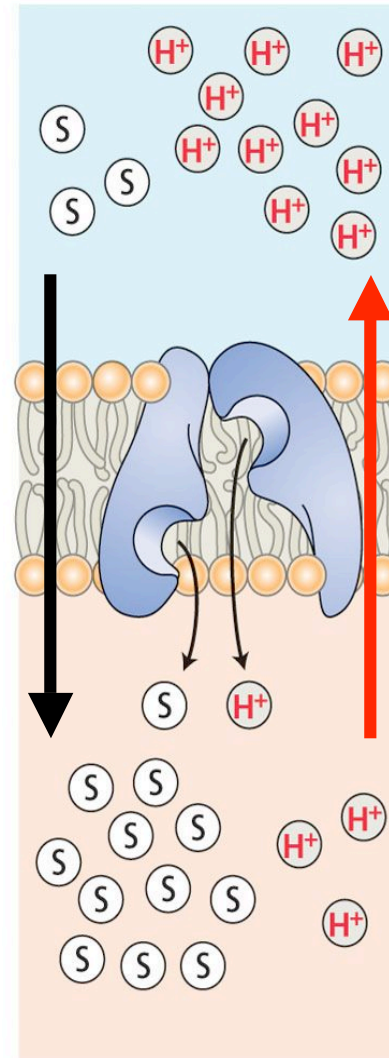
(A) Fig. 6.9



(B)



(C)



(D)

